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U1S S1820 S1990

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EP 0265144 A2 US 4973896 A

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Online databases: WPI

(54) Alternator and static converter system

(57) An alternator has a three-phase output on lines 2, 3 and 4 applied to a DC - DC boost converter circuit 5 comprising rectifier means 7 and a chopper amplifier which includes transistors 11 and 12. The necessary inductance in the convertor circuit 5 is provided by the self-inductance of the alternator 1, thus allowing the normally separately provided inductances to be omitted, with consequent savings in cost, weight and space. Power components 7, 11, 12, 13, 14 of the convertor circuit 5 may be mounted on a heat sink and included in a common unit with the alternator 1. The heat sink and the alternator may share a common cooling circuit (21, Fig. 4).

The system may be used to charge a battery in a hybrid electric vehicle.

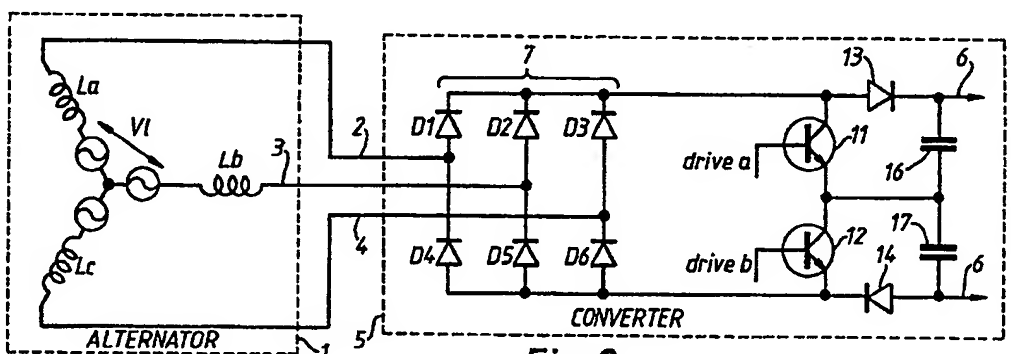

Fig. 2

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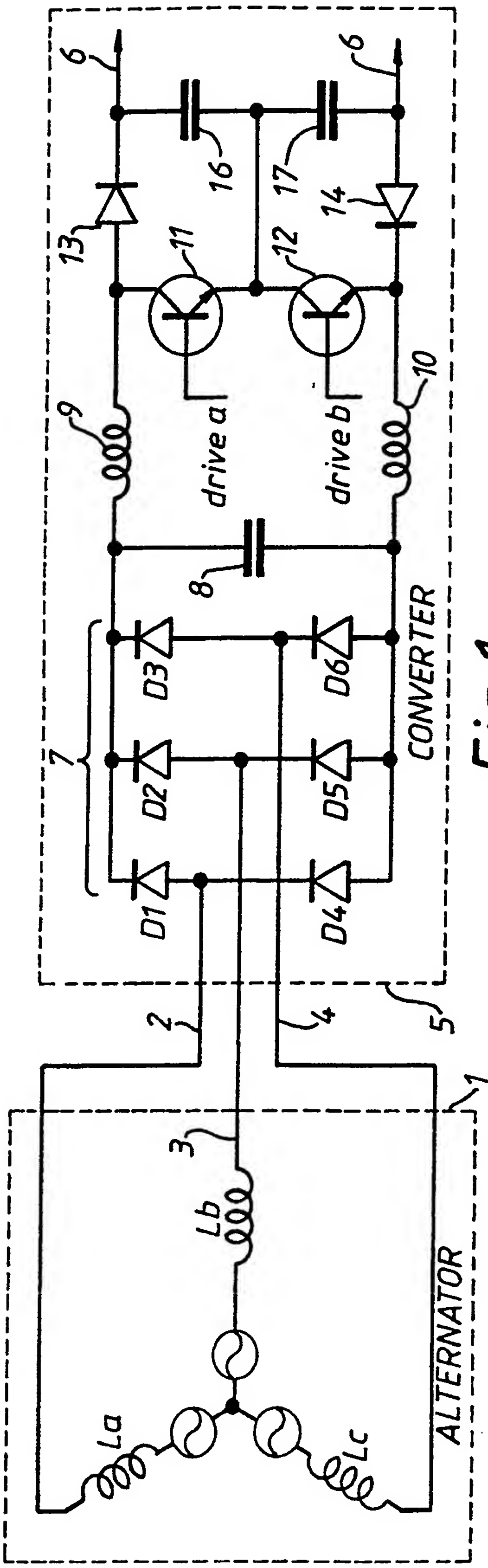
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.


CONVERTER
ALTERNATOR
drive a
drive b
D1
D2
D3
D4
D5
D6
La
Lb
Lc
1
2
3
4
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6
7
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16
17

Fig.1

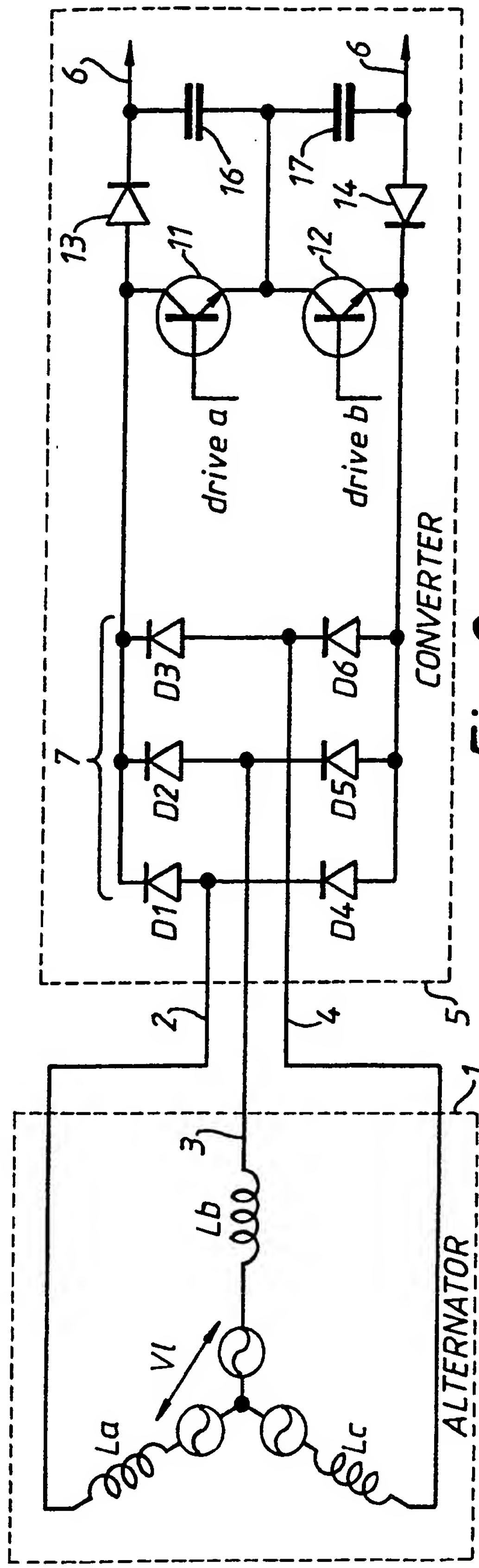
CONVERTER
ALTERNATOR
drive a
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Fig. 2

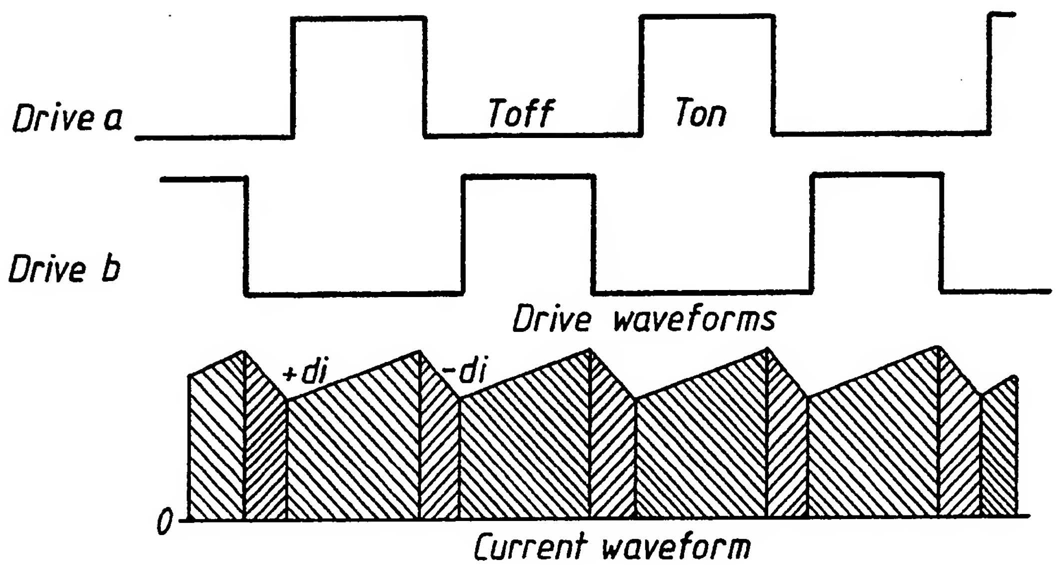
Drive a
Toff
Ton
Drive b
Drive waveforms
+di
-di
0
Current waveform

Fig. 3

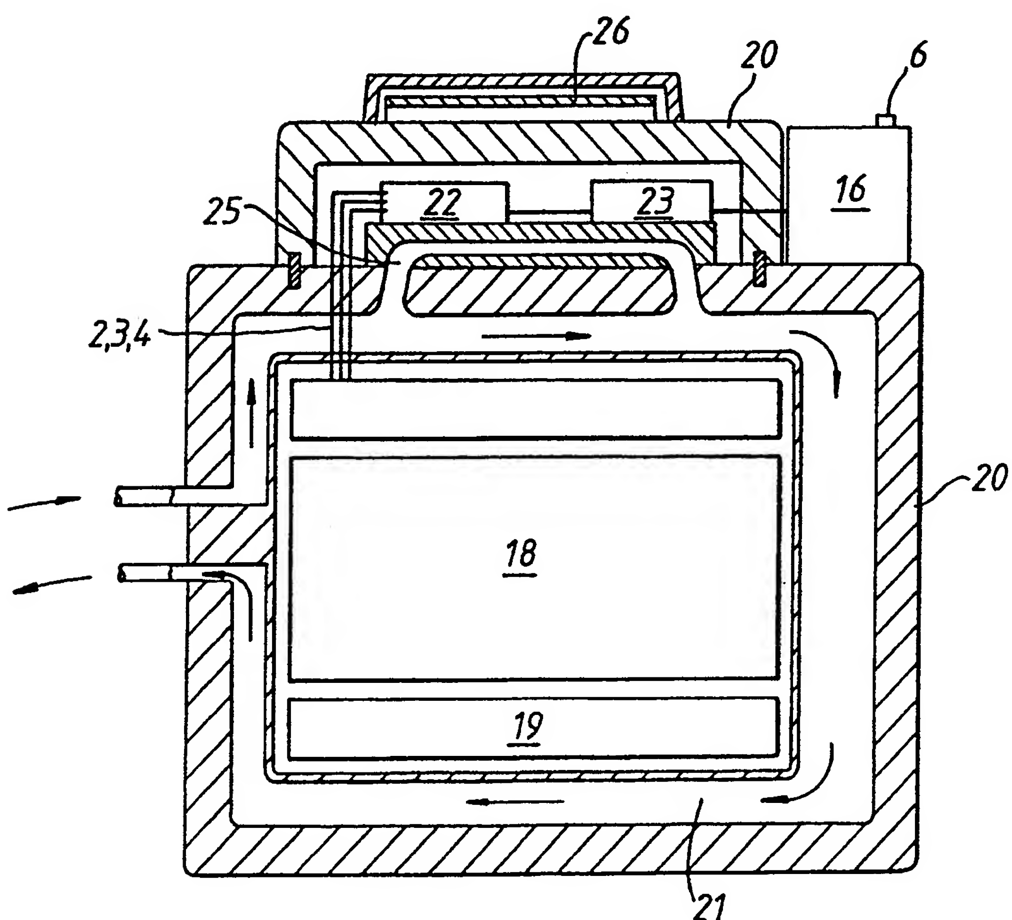
26
20
6
16
22
23
25
2,3,4
20
18
19
21

Fig. 4

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Electrical Machines

This invention relates electrical machines and more particularly but not exclusively to electrical generators suitable for use in electric vehicles.

In a known electrical generator illustrated schematically in Figure 1, an alternator 1 having a three-phase output on lines 2, 3 and 4 is connected to a convertor circuit 5 which converts the a.c. voltage to a d.c. output at its terminals 6 for application to a load. The convertor circuit 5 includes a rectifier arrangement, illustrated generally at 7, which includes diodes D1 to D6, followed by a capacitor 8 connected across it and inductors 9 and 10. Two transistors 11 and 12 are connected between the inductors 9 and 10 and are switched so as to switch current from the inductors 9 and 10 from low to high impedance paths for application via diodes 13 and 14 to capacitors 16 and 17. The transistors 11 and 12 act as a chopper amplifier to step-up the d.c. voltage across the capacitors 16 and 17.

Typically, for higher power generators, the stator of the alternator is surrounded by a water jacket or some other means for supplying coolant to it. The diodes included in the rectifier arrangement 7 are conveniently mounted on a common metal heat sink having passages therethrough via which coolant fluid may be directed and the transistors 11 and 12 may also be mounted on heat sinks for cooling purposes.

One field in which the arrangement of Figure 1 may be used is in that of hybrid vehicles which use electrical power from batteries in combination with internal combustion engines. Typically, in out-of-town driving, the internal combustion engine is used and

drives the alternator to charge the batteries attached to terminals 6. In urban use, power from the batteries only is used to drive the vehicle.

The present invention seeks to provide an improved electrical generator arrangement which is particularly suitable for use in the automotive industry but which may also advantageously be employed in other fields, particularly those where it is desirable to minimise weight and cost.

According to the invention there is provided an electrical machine arrangement comprising an alternator and a convertor circuit for converting a.c. to d.c. wherein substantially all inductance in the convertor circuit is constituted by self-inductance of the alternator.

By the term "substantially all" it is meant that although other parts of the circuit may exhibit a small inductance elsewhere, most of the inductance is derived from the alternator.

Previously, it has been thought necessary to incorporate wound components in the converter circuit for power storage. The inventors have realised that, surprisingly, it is not necessary to separately provide inductance in the convertor circuit at an alternator output contrary to the generally accepted design practice within this field. The self-inductance of the alternator viewed as part of the converter circuit provides the required power storage capability.

By dispensing with the inductors, the weight and volume occupied by the convertor circuit is significantly reduced together with the cost. Also, as fewer components are required, assembly costs are also reduced and installation is simplified. The circuit is further simplified as it is not necessary to include an input capacitor in contrast to the previously known arrangement.

In the previous arrangement the need to accommodate the two inductors and input capacitor electrically connected between the rectifier arrangement and components of a chopper amplifier leads to a relatively bulky assembly. Use of the invention enables the volume required by the remaining components to be reduced compared to that which they separately occupied previously as they may be more closely integrated.

In a particularly advantageous embodiment of the invention, components of the convertor circuit are incorporated in a common unit with the alternator.

In conventional arrangements, convertor circuit components, including the wound inductors, have been housed in an enclosure separate from the alternator. Electrical connections are required to carry the three-phase output from the alternator to the converter enclosure and separate cooling pipes to the alternator and to the enclosure are provided. By combining the convertor circuit components and the alternator within a single unit in accordance with this feature of the invention, a more compact configuration is possible. Furthermore, it enables common cooling means to be used for the alternator and power components of the convertor such as rectifier diodes and transistors and thus simplifies, for example, the cooling circuit where coolant fluid is used. The number of

external electrical connections can also be reduced as the three-phase output of the alternator need not be taken externally out from the alternator housing. Installation of the machine in a vehicle, for example, is facilitated as only one unit need be fitted having more self-contained electrical leads and components compared to the previous arrangement which consists of separate housings requiring electrical connections between them and individual cooling arrangements.

Preferably, a rectifier arrangement and a chopper amplifier are included in the common unit. The components may be located in the alternator housing, which may be a casting, for example or mounted on it to be included in the common unit. The alternator housing could consist of two parts, say, one part containing the alternator itself and the other part enclosing the components, the parts being joined together in the common unit.

One way in which the invention may be performed is now described by way of example with reference to the accompanying drawings in which:

Figure 2 is a schematic circuit diagram of an electrical machine arrangement in accordance with the invention;

Figure 3 is a diagram illustrating the operation of the arrangement of Figure 2; and

Figure 4 is a schematic sectional view of the physical arrangement of the circuit shown in Figure 2.

With reference to Figure 2, an electrical generator for use in a vehicle includes an alternator and convertor circuits similar to those shown in Figure 1, with like references being used for like parts. However, the inductances 9 and 10 and capacitor 8 which were included in the prior art generator are omitted in the arrangement in accordance with the invention.

The inductances are conventionally included to store energy after rectification to give smoothing of the current. The smoothing is aided by the chopper amplifier which switches current from a low impedance path to a high impedance path to obtain a high voltage across the final capacitors.

In circuit illustrated in Figure 2, although there may be some small inductances elsewhere within the circuit, most of the inductance is present as the self-inductance of the alternator 1. The energy storage capability of this self-inductance is sufficient to permit efficient operation of the convertor. Thus, in this arrangement, the alternator 1 also includes part of the convertor circuit 5.

The drive waveforms applied to the transistors 11 and 12 are illustrated in Figure 3. During operation, transistor 11 is switched on when drive A is positive and transistor 12 when drive B is positive. When transistor 11 is on, and transistor 12 is off, current in the alternator inductance increases at a rate determined by the difference in the line voltage V_L and the voltage across the capacitor 17 ($V_{out}/2$) divided by the alternator inductance. The path for the current flow in this condition is through the alternator inductance La, the rectifier diode D1, transistor 11, capacitor 17, diode 14, diode D6 and alternator

inductance Lc (this assumes that at this instant line 2 is the most positive line and line 4 the most negative). When transistor 11 is off, the current in the alternator inductance flows through D1 and diode 13 into capacitors 16 and 17 in series, returning through diodes 14 and D6. When transistor 12 is on, a similar action takes place but the current path is now through La, D1, diode 13, capacitor 16, transistor 12, D6 and Lc. This action increases the voltage on the capacitors 16 and 17 (V_{out}) above that of V_L. V_{out} will continue to increase until stability occurs. For stability to occur, the increase in current during the conduction period of the transistors must equal the decrease in current during the off period. The relationship between input and output voltage is given below:

$$\text{Increase in current } +di = \left(V_L - \frac{V_{out}}{2}\right) T_{on}$$

$$\text{Decrease in current } -di = (V_{out} - V_L) \quad \frac{(T_{off} - T_{on})}{2}$$

For stability +di must equal -di

$$\therefore V_L T_{on} - \frac{V_{out} T_{on}}{2} = \frac{(V_{out} T_{off} - V_L T_{off} + V_L T_{on} - V_{out} T_{on})}{2}$$

$$\therefore \frac{(V_{out} T_{off} - V_{out} T_{on} + V_{out} T_{on})}{2} = V_L T_{on} + V_L \frac{T_{off}}{2} - V_L \frac{T_{on}}{2}$$

$$\therefore V_{out} T_{off} = V_L T_{off} + V_L T_{on}$$

$$\therefore V_{out} = V_L \left(1 + \frac{T_{on}}{T_{off}}\right)$$

Figure 4 schematically illustrates a physical implementation of the circuit arrangement shown in Figure 2. The alternator 1 comprises a rotor 18 arranged coaxially within a stator 19 contained within a housing 20. The housing 20 includes a cylindrical conduit 21 arranged coaxially about the stator 19 and through which coolant fluid is

directed during use. The housing 20 also contains components of the converter circuit 5 in addition to the inductance contributed by the alternator 1 itself. Rectifiers 22 and power transistors 23 are located within the housing 20, being mounted on a common heat sink 24. The heat sink has apertures 25 therein which are in communication with the cylindrical conduit 21. Water, or other coolant fluid, flowing around the alternator 1 also cools the power components 22 and 23 of the convertor circuits. The arrangement also includes a control board 26 which is included in the common unit for controlling operation of the alternator 1, for example its output voltage and power.

The three-phase output of the alternator 1 is supplied to the rectifier arrangement via lines 2, 3 and 4 wholly contained within the housing 20.

The output of the common unit is available at terminals 6 for application to a lead, such as a battery for example.

In the arrangement shown, the components of the convertor circuit are located to the side of the alternator 1. In alternative embodiments, they may be located at one end of the alternator, on its longitudinal axis.

CLAIMS

1. An electrical machine arrangement comprising an alternator and a convertor circuit for converting a.c. to d.c. wherein substantially all inductance in the convertor circuit is constituted by the self-inductance of the alternator.

2. An arrangement as claimed in claim 1 wherein the alternator has a three-phase output.

3. An arrangement as claimed in claim 1 or 2 wherein the convertor circuit includes a chopper amplifier arranged to step up its output voltage.

4. An arrangement as claimed in claim 3 wherein the chopper amplifier includes two transistors and means for applying drive waveforms thereto.

5. An arrangement as claimed in claim 3 or 4 wherein the output of the chopper amplifier is arranged to be applied to charge storage means.

6. An arrangement as claimed in claim 3, 4 or 5 wherein components of the chopper amplifier are integrated on a common substrate with rectifier components.

7. An arrangement as claimed in any preceding claim wherein power components of the converter circuit are cooled by common cooling means.

8. An arrangement as claimed in claim 7 wherein rectifier diodes and power transistors included in a chopper amplifier are mounted on a common heat sink.

9. An arrangement as claimed in any preceding claim wherein the convertor circuit includes rectifier means and said means are included in a common unit with the alternator.

10. An arrangement as claimed in claim 9 wherein the rectifier means and the alternator are housed in a common housing.

11. An arrangement as claimed in claim 9 or 10 and wherein components of a chopper amplifier are included in the common unit.

12. An arrangement as claimed in claim 9, 10 or 11 and including common cooling means for cooling the alternator and power components of the converter circuit.

13. An arrangement as claimed in claim 12 wherein the common cooling means comprises channels via which coolant fluid is arranged to flow during use.

14. An arrangement as claimed in claim 13 wherein a channel adjacent the alternator is in communication with a channel adjacent the power components.

15. An arrangement as claimed in any preceding claim and including a control circuit for controlling operation of the alternator included in a common unit with the alternator.

16. An arrangement as claimed in any preceding claim and including a load connected across the output of the convertor circuit.

17. An arrangement as claimed in claim 16 wherein the load is a battery.

18. A vehicle including an arrangement as claimed in any preceding claim.

19. An electrical arrangement substantially as illustrated in and described with reference to Figure 2 of the accompanying drawings.

20. An electrical arrangement substantially as illustrated in and described with reference to Figure 4 of the accompanying drawings.

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9409708.6
Relevant Technical Fields (i) UK Cl (Ed.M) H2H HAF, HBCB, HBCH (ii) Int Cl (Ed.5) B60L 11/12; H02J 7/00, 7/14, 7/32; H02M 1/00, 3/04, 3/20, 7/04, 7/40	Search Examiner M J BILLING Date of completion of Search 20 JULY 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI	Documents considered relevant following a search in respect of Claims :- 1-6, 9-11

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
Y	EP 0265144 A2	(CLARK) eg. see Figure 1,8	9-11 at least
X,Y	US 4973896	(TOYO) eg. see Figure 39; column 44 line 24 - column 46 line 52	1-3,5,6 9-11 at least

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).